LEGO Goes to Sea: increasing accessibility in ocean science and engineering via kinesthetic modeling

Emma Riley, California Polytechnic State University at San Luis Obispo

Mentor: George Matsumoto

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ABSTRACT

This paper highlights the creative use of LEGO as a medium to make ocean science and engineering more accessible. Through a 10-week design-build internship at the Monterey Bay Aquarium Research Institute (MBARI), the Global Ocean Biogeochemistry Array (GO-BGC) Adopt-a-Float program was reimagined using LEGO models to represent oceanographic floats. The goal was to break down complex scientific concepts into hands-on, kinesthetic learning experiences that would inspire students and educators alike. The project led to the development of instructional guides and 17-brick LEGO float kits that were integrated into outreach activities, such as MBARI's EARTH Teacher Workshop. These kits serve as educational tools that simplify the science behind biogeochemical floats, allowing learners to connect with STEM concepts in a playful yet meaningful way. The paper also explores the potential for future LEGO-based functional models and the broader applications of LEGO in oceanographic education and research.

1. INTRODUCTION

1.1 INTRODUCTION

The Monterey Bay Aquarium Research Institute (MBARI) has long been at the forefront of marine science and engineering, pushing the boundaries of what's possible in ocean exploration. As the world of research grows ever more complex, so too does the challenge of making this science accessible to broader audiences—particularly students and educators. That's where the playful and hands-on nature of LEGO comes in. By translating intricate concepts into something as universally understood as a LEGO model, MBARI and the Global Ocean Biogeochemistry Array (GO-BGC) Adopt-a-Float program have found a way to bring the wonders of oceanography into the classroom. This collaboration seeks to bridge the gap between advanced marine research and STEM education, all while fostering a sense of curiosity and discovery. Throughout this paper, we explore how a simple LEGO float model became a powerful educational tool, sparking interest in ocean science and inspiring future generations of oceanographers and engineers.

1.2 MBARI: ADVANCING MARINE SCIENCE AND ENGINEERING TO UNDERSTAND OUR CHANGING OCEAN

The Monterey Bay Aquarium Research Institute (MBARI) has long been dedicated to advancing marine science and engineering, all in the pursuit of better understanding our ever-changing ocean. Since its founding in 1987, MBARI has been a pioneer in developing innovative oceanographic tools and pushing the boundaries of research across a variety of marine environments (MBARI, 2024). Nestled in Moss Landing, California, near the breathtaking Monterey Canyon, MBARI takes full advantage of its location to explore the diverse ecosystems that lie just beneath the surface.

MBARI's journey began with remotely operated vehicles (ROVs) and soon expanded to include autonomous underwater vehicles (AUVs) and biogeochemical sensor systems, transforming how scientists explore the deep sea and gather critical data. These breakthroughs have led to significant discoveries in areas like ocean acidification, climate change, and the incredible diversity of microbial life (MBARI, 2024). More recently, MBARI introduced new coastal profiling floats designed to monitor ocean health, particularly in nearshore regions affected by human activity. These floats capture vital data on temperature, salinity, and oxygen levels, helping scientists better understand the health of coastal waters (MBARI, 2024).

MBARI's goes beyond cutting-edge technology through programs like Adopt-a-Float, in which K-12 classrooms worldwide can "adopt" an oceanographic float and follow its journey in real-time, deepening students' connection to global ocean research while sparking interest in STEM fields. This initiative not only engages students but also raises awareness about ocean health and climate change (MBARI, 2024). MBARI's internship program further extends this outreach by offering hands-on experiences in marine research and engineering to students and early-career scientists, helping to cultivate the next generation of oceanographers.

From the development of tools like the Environmental Sample Processor (ESP) to ROVs such as Tiburon and Doc Ricketts, and AUVs like Dorado and Tethys, MBARI continues to lead the way in ocean observation. These advancements, combined with their educational initiatives and global collaborations, ensure that MBARI remains at the cutting edge of both technological innovation and public engagement in marine science (MBARI, 2024).

1.3 GO-BGC: THE GLOBAL OCEAN BIOGEOCHEMISTRY ARRAY PROGRAM

The Global Ocean Biogeochemistry Array (GO-BGC) is making significant strides in our understanding of how the ocean's biogeochemical cycles are connected to carbon cycling and climate change. By deploying autonomous floats outfitted with advanced sensors, GO-BGC collects continuous data on key ocean parameters like dissolved oxygen, nitrate, pH, and chlorophyll (GO-BGC, 2024). This data is critical for refining climate models and gaining a clearer picture of how the ocean influences global carbon storage and climate dynamics (Argo, 2024).

The GO-BGC floats, based on the Argo float design (Figure 1.3.1), are enhanced with specialized sensors that measure biogeochemical properties down to depths of 2,000 meters. These floats are giving scientists valuable insights into nutrient dynamics, ocean acidification, and the biological carbon pump—key processes that shape the ocean's role in climate change. The NOAA AOML Biogeochemical Argo Program also contributes to these efforts by deploying similar floats that track changes in oxygen, nitrate, pH, and other essential biogeochemical markers across the world's oceans. Together, these programs ensure comprehensive coverage, particularly in critical areas like the Southern Ocean and tropical Pacific, and their floats reliably collect data for 4 to 5 years (NOAA AOML, 2024; GO-BGC, 2024).

Figure 1.3.1: Illustration of a GO-BGC float by Kelly Lance, MBARI

The data collected through these programs is openly available through public repositories such as the Argo Data Management System. This open-access model fosters global collaboration and helps scientists from all over the world better understand how the ocean impacts our climate and ecosystems. These data sets are vital for advancing oceanographic research and improving the accuracy of climate models (Argo, 2024).

1.4 SOCCOM: SOUTHERN OCEAN CARBON AND CLIMATE OBSERVATIONS AND MODELING PROGRAM

The Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) program plays a critical role in helping us understand how the Southern Ocean influences the global carbon cycle and climate. By deploying a network of autonomous biogeochemical (BGC) floats, SOCCOM gathers critical data on carbon absorption and the impacts of climate change in this vital region (SOCCOM, 2024). These floats, based on the proven Argo design and equipped with cutting-edge sensors, track essential parameters like dissolved oxygen, nitrate, pH, and chlorophyll fluorescence. This allows researchers to gain near-real-time insights into carbon uptake, nutrient dynamics, and ocean acidification (Claustre et al., 2020).

SOCCOM positions its floats across the Southern Ocean to ensure comprehensive coverage of key biogeochemical hotspots (Figure 1.4.1). The data collected by these floats have painted a dynamic picture of the Southern Ocean's role as a carbon sink, revealing seasonal and annual fluctuations in carbon uptake and storage. Continuous monitoring by the program has also underscored the rapid progression of ocean acidification, particularly its growing threat to organisms that depend on calcium carbonate (Claustre et al., 2020).

A key feature of SOCCOM is its commitment to open-access data. The information collected by the floats is made available through public repositories, encouraging global collaboration and strengthening the international oceanographic research community (SOCCOM, 2024).

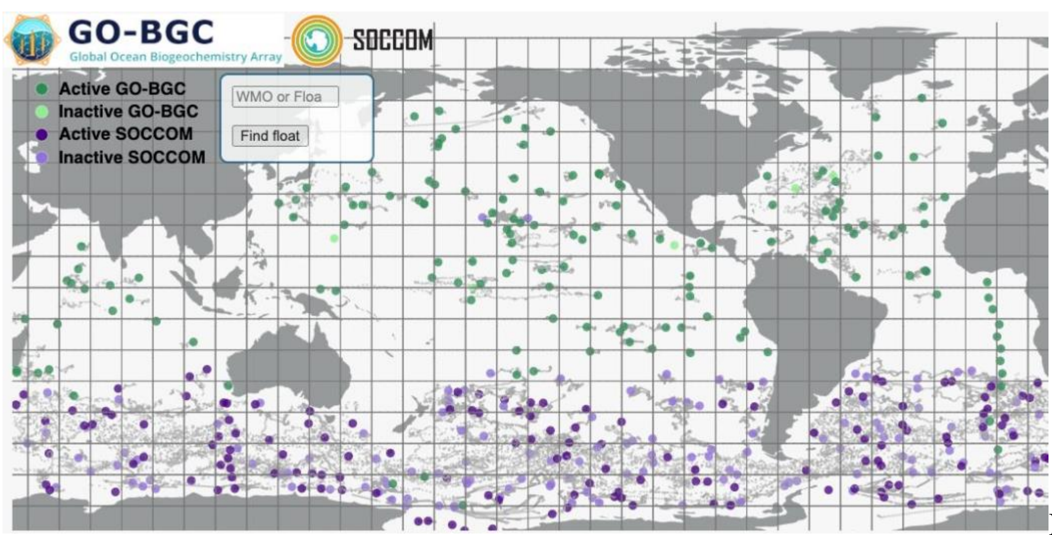


Figure 1.4.1: Global map of GO-BGC and SOCCOM floats courtesy of SOCCOM, Princeton University

1.5 MBARI'S ROLE IN SENSOR DEVELOPMENT FOR AUTONOMOUS FLOATS

MBARI has been a pioneer in developing sensor technology for autonomous oceanographic floats, playing a key role in enhancing global programs like GO-BGC and SOCCOM. Their sensors are designed to withstand the extreme conditions of the deep ocean while providing highly accurate data on a wide range of parameters (MBARI, 2024). Among MBARI's most notable innovations are optical oxygen sensors, ISUS nitrate sensors—which measure nitrate using ultraviolet spectroscopy—and advanced pH sensors, all of which are critical for monitoring ocean acidification (MBARI, 2024). MBARI has also developed bio-optical sensors, offering valuable insights into marine ecosystems by tracking phytoplankton biomass and particulate matter.

These sensors undergo rigorous field testing in diverse marine environments to ensure their reliability, and they've become essential tools in global oceanographic research. MBARI makes *all* data available to the broader scientific community through public repositories, supporting ongoing research and educational programs like Adopt-a-Float. This open-access model helps expand the reach of ocean science and fosters collaboration across the globe (MBARI, 2024).

1.6 THE ADOPT-A-FLOAT PROGRAM

The Adopt-a-Float program is a forward-thinking educational initiative that connects K-12 classrooms around the world with the excitement of real-time oceanographic research. Through this program, students and educators can "adopt" a biogeochemical float (Figure 1.6.1), which is equipped with sensors that measure key oceanographic parameters like temperature, salinity, pH, and chlorophyll (MBARI, 2024). The program's goal is to deepen students' understanding of the ocean's role in the global climate system while fostering a sense of responsibility toward marine conservation. By participating, students get hands-on experience with scientific data collection and analysis, directly contributing to global research efforts (Adopt-a-Float, 2024).

As students follow their adopted float's journey through the ocean, they receive real-time data transmitted back to shore. This data provides a window into critical ocean processes, such as carbon cycling, nutrient dynamics, and ocean acidification. With the help of educational resources, students and teachers can dive into the data, analyze it, and make sense of it—giving them a deeper connection to STEM education. Beyond just learning about oceanography, students are encouraged to explore potential careers in marine science and technology (Adopt-a-Float, 2024). The scientific contributions made by these biogeochemical floats are substantial. By filling in crucial gaps in global oceanographic datasets, the floats supply long-term, continuous data that's essential for refining climate models and improving our understanding of marine ecosystems. This data is especially important for tracking how the ocean's chemistry and biology are changing in response to climate change (Johnson et al., 2019). The open-access nature of the data enables it to be available to the global research community, promoting collaboration and supporting efforts to monitor and protect the world's oceans (Claustre et al., 2020). The Adopt-a-Float program ties this high-impact science together with classrooms worldwide, creating a unique opportunity for education and outreach both in and beyond the classroom.

Figure 1.6.1: Adopted floats awaiting deployment, photo courtesy of GO-BGC

1.7 LEGO: HISTORY AND OVERVIEW

LEGO, one of the most iconic toy brands in the world, has been captivating both children and adults for generations. Founded in 1932 by Ole Kirk Christiansen in Billund, Denmark, LEGO began making wooden toys before transitioning to the plastic interlocking bricks that are now its signature (LEGO, 2024). When LEGO introduced its brick system in 1958, it revolutionized the toy industry, sparking endless possibilities for creativity and building (LEGO, 2024). Over the years, LEGO has continued to expand its reach, creating products like DUPLO for younger children and themed sets that add a storytelling element to play (LEGO, 2024).

Throughout its history, LEGO has continued to adapt and innovate to create new opportunities for unique and compelling uses. LEGO has continuously evolved, launching advanced lines like Technic for more complex builds, the Mindstorms series that combines robotics and programming, and its latest robotics-focused series, SPIKE Prime (LEGO, 2024). But LEGO's impact goes beyond just the products themselves—it has fostered creativity and problem-solving skills in people of all ages. Staying true to its innovative spirit, LEGO has also committed to sustainability, pledging to make all core products and packaging from sustainable materials by 2030 (LEGO, 2024). From a small workshop in Denmark to a global phenomenon, LEGO's journey is one of creativity, innovation, and an enduring ability to inspire people around the world every day (LEGO, 2024).

1.8 THE USE OF LEGO IN EDUCATION: FOSTERING STEM LEARNING

LEGO's versatility and widespread appeal make it an ideal tool for engaging students in STEM education. Its hands-on, creative approach simplifies complex concepts while sparking curiosity and encouraging problem-solving. By manipulating LEGO bricks to build models, students can explore scientific principles, engineering structures, and mathematical problems in a tangible, visual way (James & Brookfield, 2014). The flexibility of LEGO as an educational tool invites students to experiment with different designs, troubleshoot challenges, and refine their creations, developing essential STEM skills such as critical thinking and innovation (Discover Engineering, 2024).

LEGO Education, a division of the LEGO Group, plays a vital role in advancing STEM learning through a variety of educational programs and resources. For example, SPIKE Prime integrates LEGO building with programmable hardware and software, offering students hands-on projects that enhance problem-solving abilities and foster creativity (LEGO Education, 2021).

Beyond the classroom, LEGO has made a significant impact in public outreach and creative projects aimed at getting more people involved in STEM fields. For instance, LEGO partnered with marine biologist Grace Young to create an "Ocean Exploration Base," a project that integrates LEGO with ocean engineering to build habitats inspired by marine science (Figure 1.8.1). This collaboration aims to inspire both children and adults by blending creativity with real-world science, encouraging a deeper interest in ocean exploration and conservation (Grace Under the Sea, 2024). Additionally, Tom Alphin, a LEGO designer, highlights the artistic side of LEGO, showing how it can be both an art form and a tool for exploring engineering concepts (TEDx Talks, 2015). LEGO Serious Play, another innovative program, uses LEGO for creative and critical reflection, helping participants think deeply about learning processes and problem-solving (James & Brookfield, 2014). From classrooms to public outreach, LEGO

continues to inspire future scientists, engineers, and innovators by making STEM education both accessible and engaging.

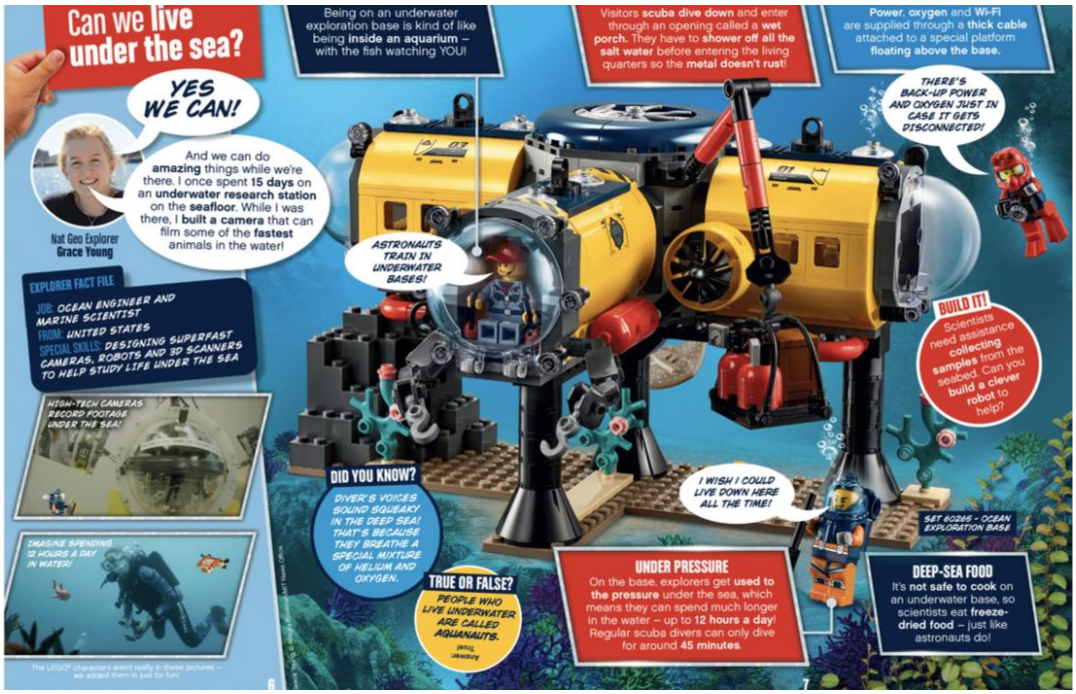


Figure 1.8.1: LEGO Catalog Supplement Fall 2020 featuring Grace Young's Ocean Exploration Base design

LEGO bricks are not just powerful educational tools; they're also becoming a burgeoning resource in scientific research. Scientists and engineers have increasingly turned to LEGO's accessibility and adaptability to create cost-effective, customizable tools for various research applications. In one innovative project, LEGO bricks are being used in ocean engineering to rebuild coral reefs in Singapore (Figure 1.8.2), proving that this simple medium can have a major impact on complex environmental challenges (Vice, 2024). In another example, LEGO has been integrated into ocean engineering research as a fun, interactive way to engage students in understanding robotics and mechanical systems (YouTube, 2024).

Figure 1.8.2: LEGO bricks used as substrate for coral reef restoration project, photo courtesy National University of Singapore

In academic settings, LEGO bricks have been widely adopted to teach core engineering and STEM concepts. Dr. Chris Rogers at Tufts University integrates LEGO Mindstorms kits into his curriculum, allowing students to design, build, and program robots, giving them a practical understanding of robotics and control systems (Rogers & Portsmore, 2005). Tufts University's Center for Engineering Education and Outreach (CEEO) has played a key role in expanding the use of LEGO in education (Figure 1.8.3), helping students and educators worldwide access innovative tools for hands-on learning (Tufts CEEO, 2024). Dr. Ethan Danahy, also at Tufts, has developed curriculum materials that incorporate LEGO robotics into project-based learning, emphasizing creativity and critical thinking (Danahy et al., 2014).

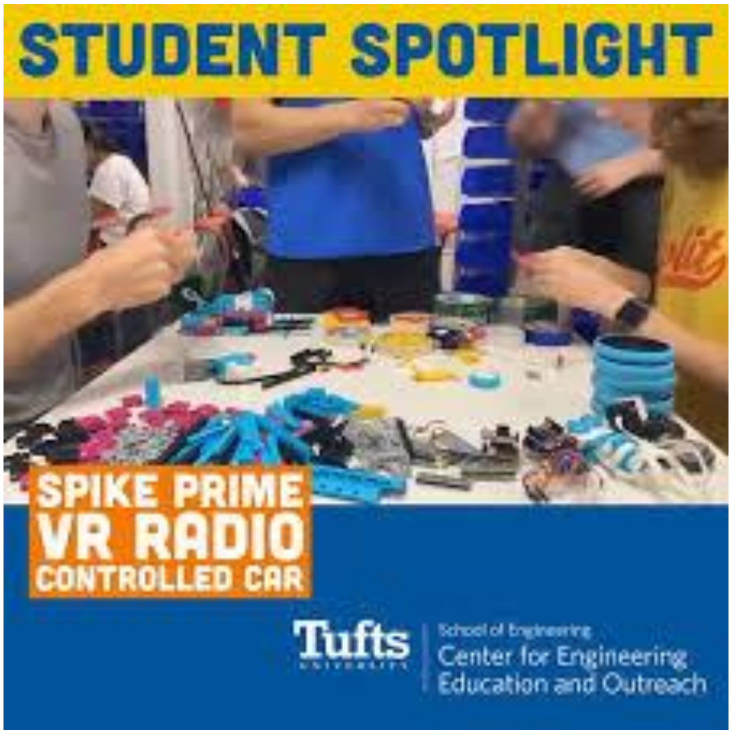


Figure 1.8.3: A student project utilizing LEGO, photo courtesy of Tufts CEEO

LEGO's impact extends far beyond traditional classrooms. For example, LEGO Serious Play encourages creative and critical reflection, helping participants solve complex problems through a playful and interactive medium (James & Brookfield, 2014). With its adaptability and universal appeal, LEGO continues to inspire future generations of scientists, engineers, and innovators, making STEM concepts more tangible and approachable for learners of all ages.

1.9 INTERNSHIP AND PROJECT DESCRIPTION: DESIGNING AND BUILDING LEGO FLOATS

The MBARI internship program offers students and early-career professionals a unique opportunity to work alongside some of the top scientists and engineers in marine research. Interns get hands-on experience with projects that contribute directly to MBARI's mission of advancing ocean science and technology, giving them valuable insights into the world of marine research and its real-world applications (MBARI, 2024).

For this particular internship project, the focus was on outreach—engaging with educators and interested partners to promote the Adopt-a-Float program. Sponsored by the National Science Foundation as part of the Global Ocean Biogeochemistry Array program, in collaboration with the NSF-funded Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project, this internship offered a unique chance to contribute to global ocean research while enhancing public engagement in marine science. The project centered around reimagining oceanographic engineering and technology using LEGO, which led to a 10-week design-build process that started with brainstorming ideas and ended with the final assembly and deliverables. LEGO models were developed to break down the complex science and engineering behind oceanographic floats, helping to create accurate small-scale representations while building a deeper understanding of their design, operation, and data collection capabilities.

Throughout the internship, instructional guides and assembly kits were crafted to serve as educational tools and outreach materials. These LEGO models became a key resource for explaining the science and engineering of oceanographic floats, helping to foster a broader public understanding of marine technology. The 10-week process involved research, conceptual design, detailed planning, and construction of each LEGO float model. Once the models were built and refined, attention shifted to creating instructional guides and custom packaging, referencing MBARI’s partner institutions in the GO-BGC program. The project culminated in a series of outreach activities, including presentations to student groups at MBARI and various invited audiences. By the end of the internship, the 3 LEGO models—representing APEX, SOLO, and Navis biogeochemical floats—had been showcased at multiple events, from the EARTH Teacher Workshop in June to the MBARI Intern Symposium in August. Along the way, the internship strengthened skills in design, engineering, teamwork, and science communication while contributing to MBARI’s mission of advancing marine science and promoting ocean literacy.

2. MATERIALS AND METHODS

2.1 INITIAL PLANNING AND CONCEPTUALIZATION

The GO-BGC program relies on autonomous floats to collect critical oceanographic data, and building LEGO models of these floats was proposed as a valuable tool for education and outreach. The goal of creating these models was to craft an engaging, hands-on way to explain the functions and significance of GO-BGC floats, raise awareness about oceanographic research, and provide ongoing educational resources for MBARI and its partner institutions.

From the start, the vision was to capture the sense of wonder, joy, and discovery that LEGO naturally inspires, guiding students on a journey to imagine and understand real-world applications in ocean science, engineering, and technology. The emphasis was on making these concepts accessible and engaging, especially for students who may have previously faced barriers—whether socioeconomic, cultural, or educational—that made STEM topics feel out of reach. LEGO, with its nostalgic, approachable nature and global accessibility, was the perfect choice for this project.

The result was a simple yet effective 17-brick, non-functional LEGO model of a GO-BGC float. Designed for easy assembly and broad understanding, the model accurately represents the float's basic shape and key components while being sturdy enough for hands-on demonstrations. Using standard LEGO bricks, the model features a cylindrical body with distinct pieces representing the pressure cases, CTD, and antenna system. Its simplicity and cost-effectiveness make this LEGO model an excellent educational tool, enabling participants to engage with the concept of GO-BGC floats in a way that is both fun and informative.

2.2 UNDERSTANDING AND MAPPING COMPONENTS

Building LEGO models of complex scientific instruments, such as oceanographic floats, involves several challenges, particularly in capturing intricate details and ensuring structural integrity. Prior existing designs of LEGO floats were created by Dirk Slawinski of CSIRO, Australia's National Science Agency (Figure 2.2.1) and utilized for outreach by the University of California, San Diego (Figure 2.2.2).

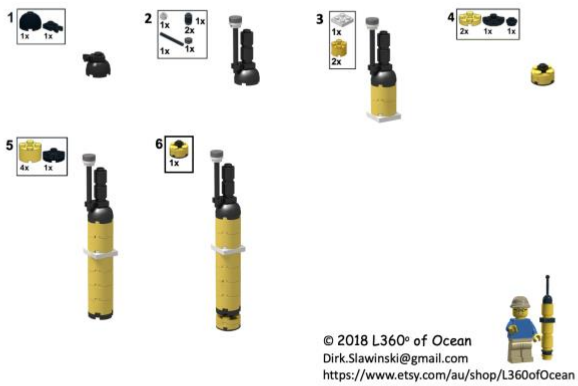


Figure 2.2.1: LEGO Float designed by Dirk Slawinski

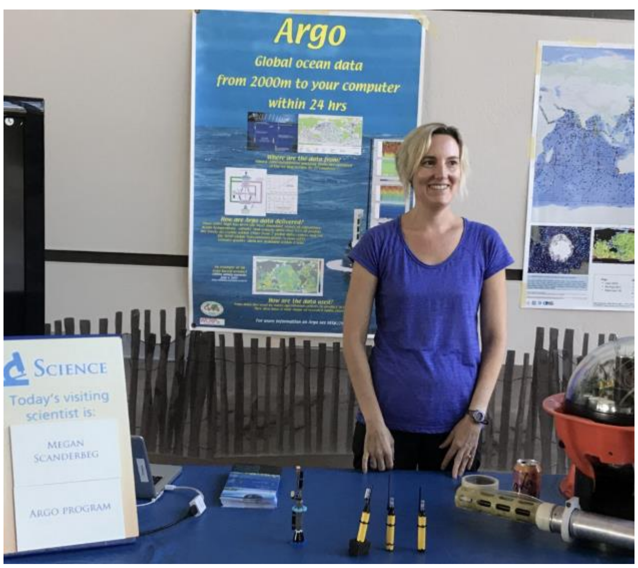


Figure 2.2.2: LEGO float models used for outreach at The Birch Aquarium

These designs provided inspiration for the sense of scale currently being used in Argo-related outreach. At the scale selected for this project, accurate representation of the float's sensors and mechanisms isn't fully realized, however the bricks selected do represent key structural and functional float components that are appropriate for the scale of a 17-brick model. LEGO Pick-a-Brick served as a repository for identifying brick codes and similar brick types to known kit components (Figure 2.2.3).

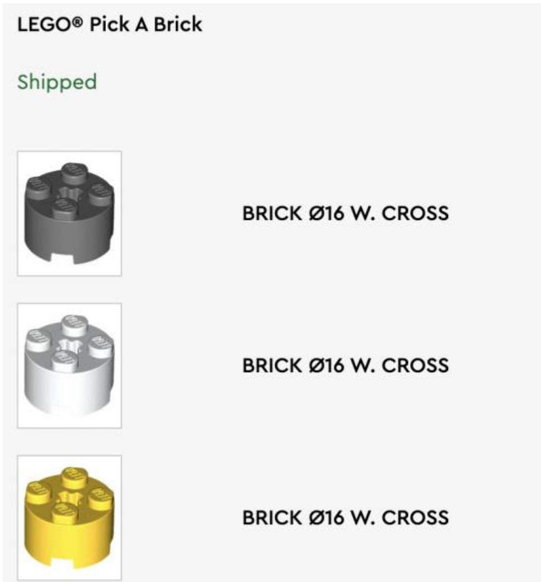
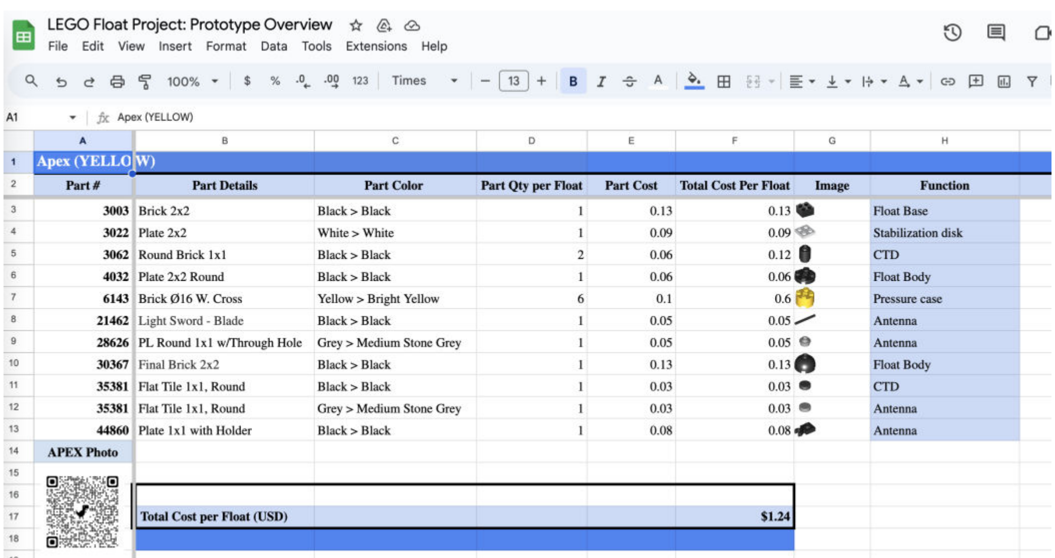


Figure 2.2.3: LEGO Pick-a-Brick search repository for identifying brick types

Further considerations and design specs for a scaled-up and functional version were fully mapped during the internship as an extension of my original assignment, and those details are further reviewed in the future directions of this paper. The design process was iterative, with multiple prototypes tested for accuracy, durability, and educational value, with individual brick codes and continual design updates tracked in a Google Sheet (Figure 2.2.4)



Apex (YELLOW)							
Part #	Part Details	Part Color	Part Qty per Float	Part Cost	Total Cost Per Float	Image	Function
3003	Brick 2x2	Black > Black	1	0.13	0.13		Float Base
3022	Plate 2x2	White > White	1	0.09	0.09		Stabilization disk
3062	Round Brick 1x1	Black > Black	2	0.06	0.12		CTD
4032	Plate 2x2 Round	Black > Black	1	0.06	0.06		Float Body
6143	Brick Ø16 W. Cross	Yellow > Bright Yellow	6	0.1	0.6		Pressure case
21462	Light Sword - Blade	Black > Black	1	0.05	0.05		Antenna
28626	PL Round 1x1 w/Through Hole	Grey > Medium Stone Grey	1	0.05	0.05		Antenna
30367	Final Brick 2x2	Black > Black	1	0.13	0.13		Float Body
35381	Flat Tile 1x1, Round	Black > Black	1	0.03	0.03		CTD
35381	Flat Tile 1x1, Round	Grey > Medium Stone Grey	1	0.03	0.03		Antenna
44860	Plate 1x1 with Holder	Black > Black	1	0.08	0.08		Antenna
APEX Photo							
	Total Cost per Float (USD)				$1.24		

Figure 2.2.4: Google Sheet created to manage prototype design and identify optimal brick types

2.3 MATERIAL SELECTION AND DESIGN

The design process advanced through the use of 3D renderings created in Stud.io, a software platform by BrickLink. Each rendering was meticulously constructed, brick by brick, by entering specific brick codes into Stud.io, followed by the digital assembly of these bricks to create a complete rendering (Figure 2.3.1) Throughout this prototyping phase, critical thinking and analysis were essential to refine key metrics such as ease of assembly, handling, base stability, design uniformity, and overall reproducibility.

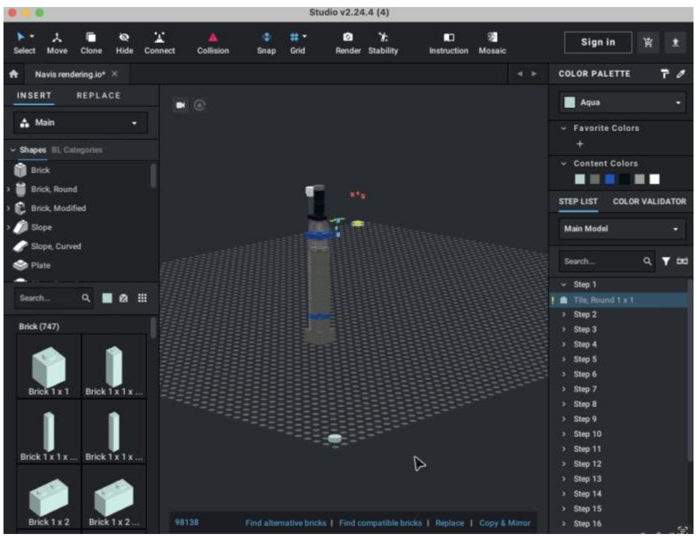


Figure 2.3.1: 3D rendering of Navis float created in BrickLink Stud.io

To optimize the workflow, the same foundational design was used for all three floats- APEX, SOLO, and Navis —differentiating them only by brick color to represent the different floats. This approach was effective for several reasons; streamlining sorting and assembly during the summer and beyond as the kits would be periodically assembled ahead of outreach efforts. It also reduced the potential for errors during the rapid assembly situations expected over the summer, such as the EARTH teacher workshop and MBARI Open House. Most importantly, the differences between APEX, SOLO, and Navis are primarily in the companies that manufacture them and the sensors they carry (Argo, 2024). At a scale of 17 bricks, these differences are negligible, as the LEGO design does not allow for the inclusion of sensors, thus minimizing any impact on the overall model.

2.4 ADDITIONAL DESIGN ELEMENTS AND CONSIDERATIONS

Beyond the bricks, packaging was needed that could securely hold the 17 LEGO pieces along with the instructional sheet. The packaging had to meet several key criteria: it needed to be durable and easy to transport without risking damage to its contents, sized just right to fit the bricks and instructions without leaving too much empty space, and user-friendly for opening, closing, and overall assembly. A special consideration for us at MBARI was that the packaging had to be free of single-use plastic. After reviewing our options, 7x5x2 flat-pack tab lock, tuck-top cardboard boxes were selected, which provided the necessary security and durability while meeting all our requirements.

Once the boxes were selected, additional packaging considerations included labels and instructional guides. Given the time constraints of the internship, over-customization was avoided in favor of a label that was readily available, fit the box dimensions, and accommodated the necessary information, including links and QR codes to GO-BGC partner institutions. Graphic design elements were added to evoke nostalgia, fun, and playfulness associated with LEGO. After testing various options, the Avery name badge template #8395 was found to meet all these criteria and could be easily ordered in bulk. In consultation with a coordinator at MBARI, potential challenges related to mass-printing labels, particularly issues with alignment and quality control when designing and printing directly within the Avery online template, were identified. These insights ultimately led to a practical solution.

The label design was crafted using Canva Pro, which allowed for the creation of a playful title graphic and seamless integration of the QR codes linked to partner institutions (Figure 2.4.1) . These QR codes were generated using Adobe QR Code Generator. Once the design was completed, the labels were saved in bulk from Canva Pro and uploaded into the Avery template. This approach—importing a fully finished design rather than designing directly in Avery—completely resolved the formatting and printing issues.

Screenshots of the process were shared with the coordinator to support future projects. It is recommended to always import finished designs into Avery, regardless of the design tool used, as they can be in any .pdf, .jpg, or .png format.

Figure 2.4.1: LEGO Float assembly instructions created in Canva Pro

The final task involved creating the instructional guides, bringing together many of the design elements developed throughout the process. The cover page featured the graphic originally designed for the label, while the back page showcased a custom graphic created using 3D renderings of the LEGO float designs. QR codes linking to GO-BGC partner institutions were also included, reinforcing the kits' role as educational outreach tools. To support educators, a page with resources and lesson plans available through MBARI Education and EARTH workshops was added. The step-by-step assembly instructions were created using the instruction-building feature in Stud.io, which allowed for the generation of detailed guides directly from the brick renderings. These instructions were then imported into Canva Pro for resizing, editing, and final adjustments. The finished instructional guide was a six-frame, tented trifold that fit neatly atop the bricks inside each LEGO box, creating a complete LEGO float model kit.

3. RESULTS

3.1 COMPLETED LEGO FLOAT MODEL KITS

The design of the LEGO float kits is a perfect blend of thoughtful engineering, creative design, and educational purpose (Figure 3.1.1). Each kit is packaged in a durable, eco friendly 7x5x2 flat-pack tab lock, tuck-top mailer box, chosen specifically for its functionality and sustainability (Figure 3.1.2).

Figure 3.1.1: Finalized 3D rendered LEGO float designs, graphic created by Emma Riley in BrickLink Stud.io

Figure 3.1.2: Finalized LEGO float kits in their cardboard flat-pack boxes, affixed with custom labels

Inside, the kits contain 17 carefully selected LEGO bricks, each representing a key component of the float design, along with a well-crafted six-frame instructional guide. This guide, presented in a tented trifold format, features a cover graphic that captures the playful spirit of LEGO while also incorporating educational elements like QR codes linking to GO-BGC partner institutions and MBARI EARTH educator resources. The instructions, generated from 3D renderings in Stud.io and refined in Canva, make it easy for users to assemble the floats, turning the kits into a hands-on learning tool that is both creative and functional.

The kits were designed with accessibility in mind, reflected in the cost—each float can be built for about $1.24, covering the 17 necessary bricks. The instructional guides and labels, published via Canva Pro, are easily accessible to the public. This final design is the result of careful planning and a commitment to creating an engaging and educational experience for everyone who interacts with these kits.

3.2 CASE STUDY: BRINGING LEGO FLOAT DESIGNS TO THE 2024 MBARI EARTH TEACHER WORKSHOP

The 2024 MBARI EARTH Teacher Workshop, held at the University of Washington in Seattle, provided a unique platform for educators to explore innovative ways to engage students in oceanography and marine science. This annual workshop has a long history of fostering collaboration between teachers and scientists, with the goal of equipping educators with the latest tools and resources to inspire the next generation of learners. A key highlight of this year's workshop was the introduction of the LEGO float kits—an educational tool designed to make complex oceanographic concepts accessible and engaging for students of all ages.

At the workshop, teachers had the chance to interact with early designs of the LEGO float kits (Figure 3.2.1). These kits, carefully crafted to balance durability, ease of use, and educational value, allowed participants to build their own LEGO floats using the 17-brick configurations developed during my internship. The instructional guides, which featured custom graphics, QR codes to GO-BGC partner institutions, and educator resources from MBARI Earth, played a central role in the workshop experience. These guides ensured that each participant could not only assemble their LEGO floats (Figure 3.2.2) but also grasp the scientific principles behind them.

Figure 3.2.1: Educators assembling LEGO floats at the MBARI EARTH teacher workshop. Photo by Jenn Magnusson.

Figure 3.2.2: Educators utilizing instructional guides for assembly of floats (from L to R: APEX, SOLO, and Navis), photo courtesy of Stacey Sebert

Several teachers chose to integrate these LEGO floats into their EARTH lesson plan assignment, "LEGO Build a Float," which is designed to teach students about buoyancy, density, and the role of oceanographic floats in monitoring the world's oceans (Figure 3.2.3). By using the resources and tools I had developed—including the original brick inventory, instructional guides, and screenshots of my activities—the educators saw firsthand how these kits could enhance classroom learning. This hands-on approach allowed them to experience the effectiveness of the kits in conveying complex scientific concepts in a fun and engaging way.

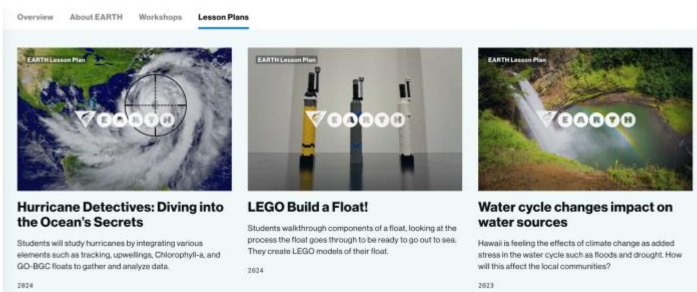


Figure 3.2.3: LEGO Build a Float lesson plan on the MBARI EARTH main page

One of the key lessons learned from this experience was the importance of adaptability in educational tools. Feedback from the teachers highlighted the value of having a versatile and well-thought-out design that could be easily implemented in different educational settings. Additionally, the workshop underscored the need for clear and concise instructional materials—the initial instructional guides shared with educators were via QR code, and feedback from the educators indicated the preference for a printed instructional guide, further adding to the tactile nature of the project. In visiting the real APEX floats at the UW Float Lab (Figure 3.2.4), educators were able to compare features of the LEGO floats with the life-size floats and deliver feedback about accuracy at scale. While the assembly process during the EARTH workshop was highly interactive, with the educators selecting their own bricks, future iterations of similar workshops utilizing the LEGO floats will benefit from the ability to streamline the printing and assembly processes.

3.3 LEGO FLOAT KITS AT WORK: A SUMMER OF USE IN MBARI OUTREACH

Throughout the summer, the LEGO float kits proved invaluable as both educational and outreach tools, engaging a wide range of students and visitors in the wonders of oceanographic science. These kits not only stood out during various student tours but also served as a tangible bridge between the playful world of LEGO and the complex, fascinating realm of marine research. One highlight was the visit from students in the Monterey Peninsula College ROV internship. This program, which focuses on remotely operated vehicle (ROV) technology, attracts students passionate about marine robotics and underwater exploration. During their tour, the LEGO float kits offered a hands-on introduction to the principles of buoyancy and stability—key concepts in both ROV design and oceanographic floats. By showcasing the design-build process and 3D renderings, the students were provided with a new perspective, helping them gain a deeper understanding of the engineering challenges involved in creating stable, functional marine devices (Figure 3.3.1).

Figure 3.3.1: Showcasing 3D renderings of LEGO float designs to visiting ROV interns from Monterey Peninsula College. Photo by Kevin Raskoff.

The kits also made a significant impact on visiting students from South Korea, who were part of the 2024 Youth Global Science Expedition. This program brings together young science enthusiasts from around the world to explore cutting-edge research and its applications. During their visit, the students had the chance to practice launching their own LEGO floats off the LEGO Ocean Explorer ship using minifigs, adding an element of fun while reinforcing key oceanographic concepts (Figure 3.3.2). Another group that benefited from the LEGO float kits was the BridgeBuilders LA program, which focuses on empowering underserved youth through STEM education.

Figure 3.3.2: Demonstrating LEGO floats aboard a LEGO Ocean Explorer ship for visiting Youth Global Science Expedition students from South Korea. Photo by George Matsumoto.

The kits also played a role at the Chemical Sensors Lab tent during the MBARI Open House, an event that attracts a diverse audience ranging from local families to dedicated science enthusiasts. At this event, the kits were displayed as a bridge between science and education, allowing visitors of all ages to engage with oceanographic concepts in a fun and accessible way. The LEGO floats helped demystify the sophisticated technology used in marine research, making it approachable and engaging for everyone, from young children to adults. Beyond these specific groups, the kits were used throughout the summer to engage visitors and the public in various ways. Whether through informal talks, hands-on demonstrations, or educational displays, the LEGO float kits consistently drew interest and excitement, highlighting the intersection of creativity, engineering, and marine science. They served not only as educational tools but also as symbols of how complex scientific ideas can be communicated to the public in innovative ways. During my internship, the LEGO float kits effectively bridged the gap between scientific research and public outreach, making oceanographic science accessible and exciting to a broad audience. As they continue to be used in future programs and events, these kits will leave a lasting impression on all who interact with them, inspiring a deeper appreciation for the ocean and the technology used to study it.

4. DISCUSSION

4.1 DISCUSSION OF FUTURE DIRECTIONS

While the design and construction challenges of the 17-brick LEGO float models were covered in 2. Materials and Methods and 3. Results, those discussions mainly focused on completing the internship project. These non-functional models were created with cost-effective, large-scale educational and outreach efforts in mind. Looking ahead, the next exciting step is to scale up these designs to create functional, robotic versions. Building a LEGO float capable of profiling in water presents some unique engineering challenges.

The first challenge for any LEGO project is identifying the right brick types and deciphering inter-brick compatibility, essentially figuring out how they fit together. As discovered during this internship project, the learning curve can be steep, particularly in early stages of brick identification, as well as when it comes to up-scaling or translating design into mechanical functionality. A significant opportunity exists to develop a more functional system for categorizing bricks, including easily identifiable keywords or symbols to quickly determine if two bricks will fit together.

For a functional LEGO float, one of the main engineering hurdles will be ensuring that the float is both waterproof and structurally sound, as standard LEGO pieces aren’t designed to be waterproof. This could be addressed by sealing joints with silicone and creating watertight housings for the electronics. Another challenge is controlling buoyancy with precision. A potential solution could be integrating a LEGO Mindstorms motor with a piston or bladder system to adjust buoyancy as needed.

Incorporating sensors presents its own set of difficulties due to their size and the need for waterproofing, but small, waterproof sensors could be securely mounted to the float. The float would also require lightweight, rechargeable batteries stored in watertight compartments to maintain proper buoyancy. Data logging and transmission underwater would need careful consideration, possibly using local storage or a waterproof wireless module.

Ensuring stability and maneuverability in different water conditions is another key concern. This could be improved by designing the float with a low center of gravity and incorporating adjustable fins or rudders controlled by LEGO Mindstorms motors. Regular testing and calibration would be essential to ensure the float operates as expected, and a modular design would make ongoing maintenance much easier.

4.2 FUTURE LEGO MODELS FOR MBARI: FUNCTIONAL CONSIDERATIONS

LEGO models offer a creative and engaging way to bring complex oceanographic tools and concepts to life. At MBARI, future projects could explore building detailed LEGO models of gliders, biogeochemical floats, and other marine research instruments. These models would feature key components like buoyancy control systems, sensors for various measurements, and communication systems—all designed to mimic the real-world principles of underwater gliding, autonomous navigation, and data collection.

For example, a LEGO model of an underwater glider could include a main body, wings, tail, buoyancy control system, and sensors for measuring temperature, salinity, and pressure, along with a communication antenna. Measuring about 30 cm in length, the model would demonstrate how gliders work, from adjusting buoyancy to collecting data.

Built using LEGO Technic pieces for durability and stability, this model would closely resemble actual glider designs. Buoyancy control could be simulated using a LEGO Mindstorms motor connected to a piston or bladder system, allowing for precise adjustments. Adjustable wings using Technic hinges would enable the model to demonstrate different gliding paths, while small LEGO-compatible sensors could connect to a LEGO Mindstorms programmable brick to simulate real-time data logging and transmission. Waterproofing techniques, such as silicone sealant or custom 3D-printed housings, would protect the electronics, and a LEGO antenna piece could integrate Bluetooth or infrared components for data transmission in controlled environments.

Similarly, a LEGO model of a biogeochemical float could feature a float body, buoyancy control system, sensors for measuring temperature, salinity, pH, and nitrate, and a communication antenna. Standing roughly 25 cm tall, this model would demonstrate vertical profiling, data collection, and remote communication. The float body, constructed from LEGO Technic pieces, would provide stability and closely resemble actual biogeochemical floats. A buoyancy control system could be implemented using a LEGO Mindstorms motor linked to a piston or bladder mechanism, allowing for precise adjustments. Adjustable ballast weights made from Technic parts could ensure the float stays upright during demonstrations. Sensors for temperature, salinity, pH, and nitrate could be integrated and connected to a LEGO Mindstorms brick to simulate real-time data logging, while waterproofing techniques would protect the electronics and sensors. The communication system could be represented by a small LEGO antenna piece, potentially integrating Bluetooth or infrared components for data transmission. Like the glider model, this float would have a modular design, making it easy to assemble, maintain, and upgrade.

These models would be invaluable educational tools, helping to explain the dynamics of marine technology, teach principles of buoyancy, stability, and navigation, and engage students in hands-on learning. By creating detailed LEGO models of tools like gliders and biogeochemical floats, MBARI could offer unique educational opportunities that bring oceanographic research to life. These LEGO-based tools could be showcased at events like Open House and student tours, increasing their impact on the next generation of marine scientists and engineers. By incorporating these models into MBARI's science communication and social media efforts, the institute could broaden its global reach and enhance public understanding of oceanographic research and technology.

5. CONCLUSIONS/RECOMMENDATIONS

5.1 FUTURE DIRECTIONS: RECOMMENDED MBARI-LEGO PARTNERSHIP

A future partnership between LEGO and MBARI could revolutionize oceanographic research and education by introducing engaging, hands-on tools for students and researchers alike. One exciting concept is the development of an interactive coding platform where students can program virtual oceanographic vehicles. By combining LEGO's intuitive building elements with an accessible coding interface, students could simulate real-world missions, learning coding skills as they guide virtual vehicles to collect ocean data. This platform would serve as a powerful introduction to both ocean science and computer programming, encouraging problem-solving and experimentation in a virtual marine environment.

In addition to the coding platform, a LEGO-based marine ecosystem simulator could offer students a tangible way to understand how environmental changes affect marine life. With this system, students could physically build various ocean habitats, then observe how factors like temperature, pH, and pollution levels impact marine organisms. This hands-on approach would provide a dynamic learning experience, allowing students to explore complex ecological relationships and grasp the delicate balance of factors that sustain marine ecosystems.

Finally, an augmented reality (AR) app could further bridge the gap between the digital and physical worlds. By overlaying real-world ocean data onto LEGO-built models, users could visualize and interact with ocean phenomena in a completely new way. Imagine building a LEGO model of a deep-sea vent, then using the AR app to project real-time data onto the model, showing temperature gradients, chemical compositions, and marine life interactions. This immersive experience would make ocean science more engaging and accessible, deepening users' understanding of the complex processes that govern our oceans.

Initiatives such as these, realized through a LEGO-MBARI partnership, could empower the next generation of oceanographers and engineers, making ocean science both approachable and exciting. Integrating LEGO’s sense of innovation and creativity with MBARI’s cutting-edge technologies would allow ocean enthusiasts of all ages to develop a deeper connection to marine ecosystems and technologies.

5.2 FUTURE DIRECTIONS: RECOMMENDED MBARI-OCEANX PARTNERSHIP

MBARI and OceanX, both leaders in marine science and technology, have the potential to form a powerful partnership in education and outreach by tapping into the universal appeal of LEGO. With MBARI’s cutting-edge research and OceanX’s storytelling expertise, they could collaborate to inspire and educate diverse audiences about the wonders of ocean science. One of the key initial projects could be the development of educational kits that use LEGO to model oceanographic tools like ROVs, AUVs, and biogeochemical floats. These kits, complete with lesson plans, activity guides, and instructional videos, would make complex scientific concepts more accessible and engaging for students. Joint outreach events, featuring hands-on building stations and interactive exhibits at aquariums, schools, and public festivals, could further bring the excitement of marine science to life for people of all ages. Beyond creating educational kits and hosting public events, the collaboration could also explore several other innovative ideas. For example, they could develop immersive Virtual Reality (VR) expeditions, allowing users to virtually join deep-sea missions and explore underwater ecosystems from their classrooms or homes. As a long-range effort, they could host ocean-themed art and science exhibitions, blending OceanX’s exploration footage with MBARI’s scientific data, presented through interactive LEGO displays and pre-built LEGO installations. These exhibitions could travel to major cities, aquariums, and science museums, using the combined power of art and science to spark public interest in ocean conservation and cutting-edge marine research. By combining their strengths, MBARI and OceanX could create groundbreaking educational tools and outreach programs that not only enhance public understanding of ocean science but also inspire the next generation of ocean advocates and scientists.

5.3 CONCLUSION

The integration of LEGO into GO-BGC floats during this MBARI internship showcases the potential for playful learning tools to engage the public in ocean science. By translating the complexity of biogeochemical floats into 17-brick LEGO models, this project not only made oceanographic concepts more accessible but also created a tangible connection between STEM education and real-world marine research. The success of the LEGO float kits in outreach activities demonstrates the power of kinesthetic learning in fostering curiosity and understanding among students and the public alike.

Looking forward, the use of LEGO in ocean science could evolve further, with potential for creating functional, programmable models that go beyond representation to active participation in research simulations. From educational workshops to global science initiatives, these models could serve as a bridge between creativity, technology, and marine science, empowering the next generation of oceanographers and engineers. This project has laid the foundation for ongoing innovation at the intersection of education, design, and marine research, ensuring that the wonder of ocean science and the innovation of ocean engineering remain accessible to all.

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